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Rillenkarren on Gypsum in Nova Scotia
Lapiès de fissure sur gypse, en Nouvelle-Écosse

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Résumé de l'article

Les lapiès de fissure (rillenkarren) sont des formes de ruissellement qui se présentent comme des cannelures groupées sur des pentes. Leur largeur dépasse rarement quelques centimètres; leur longueur dépend de l'étendue de la roche à nu sur le versant. Les lapiès s'observent dans beaucoup de régions karstiques et sur différents types de roches. On a mesuré des lapiès de fissure dans quatre sites de la Nouvelle-Écosse, puis on a comparé les résultats avec des données trouvées antérieurement sur les lapiès de fissure sur calcaire. Il en ressort que les lapiès de fissure sur gypse sont généralement plus étroits que les lapiès sur calcaire. On n'a pu établir leur longueur moyenne parce qu'elle était limitée par la longueur de la surface à nu. Ces conclusions sont le résultat de la première étude systématique menée sur les lapiès de fissure naturels et diffèrent des dimensions déjà rapportées par différents auteurs.

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Note

RILLENKARREN ON GYPSUM IN NOVA SCOTIA

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ABSTRACT Rillenkarren are defined as densely packed, rainfall generated, bedrock channels, forming on slopes. They are usually no more than a few centimetres in width. Their lengths are dependant on the downslope extent of exposed bedrock, Rillenkarren exist in many karst terraines on many types of rock. Rillenkarren on gypsum were measured at four differing sites in Nova Scotia. The results are compared with previous data for naturel rillenkarren on limestones. It was found that gypsum rillenkarren tend to exhibit a smaller mean width that those on limestone. Mean lenghts could not be established because rillenkarren elongation on the gypsum was limited by the length of the exposed surface. These conclusions result from the first systematic study of naturally occurring rillenkarren on gypsum and are contrary to the previously speculated dimensions reported by various authors.

RÉSUMÉ *Lapiès de fissure sur gypse, en Nouvelle-Écosse*. Les lapiès de fissure (*rillenkarren*) sont des formes de ruissellement qui se présentent comme des cannelures groupées sur des pentes. Leur largeur dépasse rarement quelques centimètres; leur longueur dépend de l'étendue de la roche à nu sur le versant. Les lapiès s'observent dans beaucoup de régions karstiques et sur différents types de roches. On a mesuré des lapiès de fissure dans quatre sites de la Nouvelle-Écosse, puis on a comparé les résultats avec des données trouvées antérieurement sur les lapiès de fissure sur calcaire. Il en ressort que les lapiès de fissure sur gypse sont généralement plus étroits que les lapiès sur calcaire. On n'a pu établir leur longueur moyenne parce qu'elle était limitée par la longueur de la surface à nu. Ces conclusions sont le résultat de la première étude systématique menée sur les lapiès de fissure naturels et diffèrent des dimensions déjà rapportées par différents auteurs.

ABSTRAKT Żłobki bruzdowe, (karrenrillen) są zdefiniowane jako gęsto rozmieszczone rozcięcia linijne podłoża skalnego powstałe na stokach w wyniku działania wód deszczowych. Formy te mają azawyczaj szerokość nie wieksza od kilku centymentow. Ich długość jest zależna od długości odsłonięcia powierzchni skalnej na stoku. Żłobki bruzdowe wstępuja na wielu obszarach krasowych i na róznym podłożu skalnym. Formy powstałe na gipsach były mierzone w czterech odsłonięciach w Nowej Szokocju. Resultaty pomiarow sa porównane z poprzednimi danymi odnośnie żłobków bruzdowsych zozwinietych na wapieniach. Stwierdzono że gipsowe żłobki bruzdowe mają większe średnie wartosci szerokości żłobków niż odpowiednie formy rozwinięte no wapieniach. Srednie długości żłobków nie zostały wyliczone ze względu na to że pomiar podłużnych osi bruzd był ograniczony długoscią expozycji skalnej. Resultaty badań, oparte na pierwszychm systematycznie prowazonych studiach nad żłobkami bruzdowymi rozwiniętymi na gipsach, są sprzeczne z poprzednio publikawanymi spekulatywnymi wynikami różnych autorów.

INTRODUCTION

Ford and Williams (1989, Table 9.1, page 376-377) define the numerous karren forms typically associated with karst landscapes. Rillenkarren are placed in the category "Linear forms — hydrodynamically controlled" and the category "Gravitomorphic solution channels". Rillenkarren are described as solution channels which "head at the crest of a bare slope and diminish in depth down slope until they are replaced by a planar solution surface, the Ausgleichflache" (Ford and Williams, 1989, p. 384). Figure 1 defines the place of rillenkarren within the general set of karst karren forms.

A few authors have reported on the dimensions of rillenkarren found on limestone (*e.g.* Bögli, 1960; Glew, 1976; Lundburg, 1977; Dunkerley, 1979, 1983). To date, the only studies of naturally occurring rillenkarren on gypsum of which the authors are aware are Czok (1990) and the present work. It has been noted, by casual observation, that there is little morphologic difference between limestone and gypsum (Jennings, 1985; White, 1988; Ford and Williams, 1989). though the latter hint that rillenkarren on gypsum have "characteristic widths (which) appear to be a little greater than on the carbonates".

Gypsum is abundant in outcrop in Nova Scotia, where it is extensively quarried. The formation of rillenkarren on erosional surfaces of differing origin and differing age was studied in 1989 at four sites (Fig. 2). The results are analyzed below. It may be noted that, in all cases, even a thin layer of debris (usually shillow) inhibited the formation of any karren. Length of the karren was limited by the length of the exposed, clean bare rock surfaces (usually < 1 m but occasionally up to 3.5 m), so that no clear relationships between length and gradient could be established. No channel narrowing occurred such as is noted with typical decantation karren. Although some bifurcation or braiding took place it was minor

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in most cases and had no effect on the size or shape of individual rillenkarren. In only a very few places did the karren terminate and this was a result of drastic changes in slope.

The first site (St. Croix no. 1) is a road cut near the Village of St. Croix which provides a series of sheer walls (75° to 90°) with less steep exposures along their crest. Away from the cut a thin veneer of till covers the gypsum and prohibits all rillenkarren formation. A Canada Department of Mines map identifies the road as present before 1909. However, no date could be established for the present road cut. Residents of the area claim that regular removal of debris is necessary, implying that many of the steep surfaces are probably younger than the time elapsed since 1909. The gypsum is fine grained, clean white with no obvious bedding. Joint sets are 2.5 to 3 m apart and show little solution.

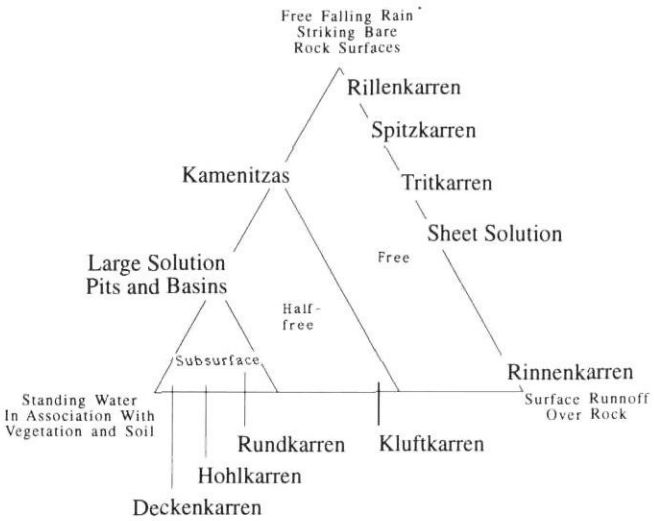

FIGURE 1. A conceptual classification of karren within a ternary diagram.

Classification conceptuelle des lapiès (karren) *dans un diagramme triangulaire.*

Along the St. Croix River karren were found on a cliff face created by lateral erosion by the river (St. Croix no. 2) and on exposed walls of dolines and caves (St. Croix no. 3). In the cliff walls patches of anhydrite can still be identified. The karren measured here are generally formed in this anhydrite rather than on the more friable (hydrated) gypsum. It may be surmised that the rillenkarren surfaces here are very young (<40 years) due to the rapid rates of cliff erosion in weak, soluble rocks. The dolines and caves are in a relatively clean, fine grained white gypsum. Selenite was noted in veins along major joints but had no effect on the rill development.

The Cape North site is the floor of an abandoned quarry. It is of special interest for two reasons. First, the quarrying exposed a variety of surface slopes and second, the quarrying took place for a short period of time and ended completely around forty years ago (1947-1952). This provides a precise maximum time period during which these features could have formed. The rillenkarren occur on gypsum that has been hydrated (much of it during the last 40 years) from anhydrite exposed by quarrying. The gypsum is generally fine grained with a mottled appearance.

It can be asserted that all of the studied surfaces are young when compared to those commonly investigated in limestone karren areas. The gypsum surfaces are probably not more than 100 years old at most; those in the quarry are between 36 and 42 years in age. Figures 3a and 3b show typical rillenkarren found at these sites.

The rillenkarren commonly occur in small, scattered patches because many surfaces are covered in a thin layer

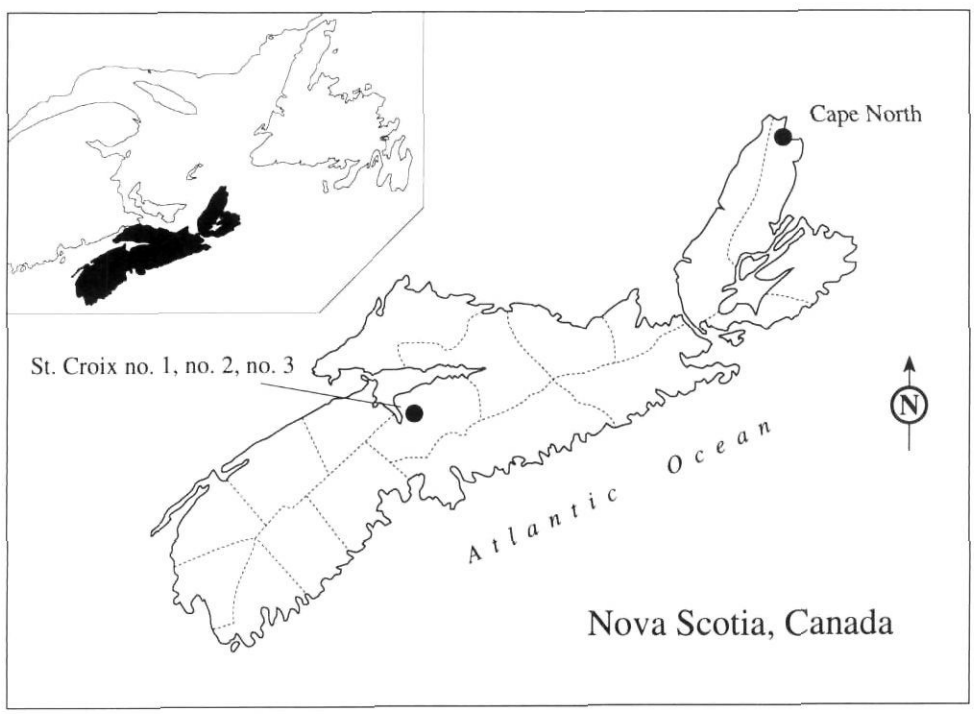

FIGURE 2. Location of the St. Croix and Cape North sampling sites, Nova Scotia.

Localisation des sites d'échantillonnage de St. Croix et de Cape North, en Nouvelle-Écosse.

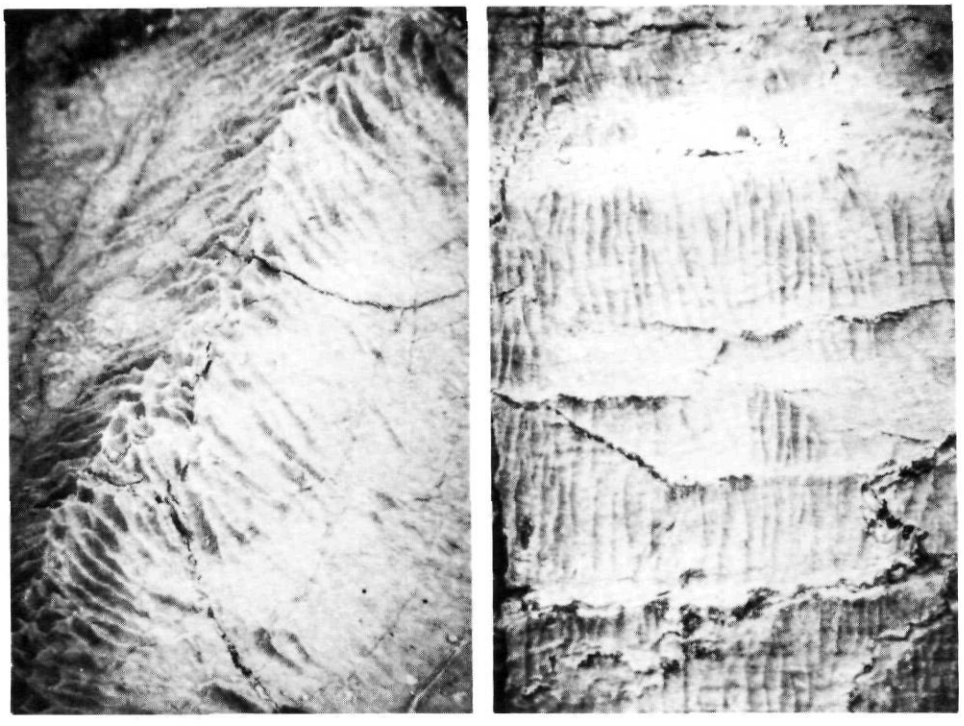

FIGURE 3. (a) Rillenkarren on a quarry wall, Cape North. (b) Close up of rillenkarren at Cape North.

a) Lapiès de fissure sur la paroi d'une carrière (Cape North). b) Détail de lapiès à cannelures (Cape North).

TABLE I

Gypsum Rillenkarren Summary Statistics

Site	Mean Width	Mean Depth	Mean Slope (in degrees)	Mean w/d	N	Density /cm
St. Croix 1	0.87 [0.28]	0.22 [0.08]	32 [26]	4.22	27	1.15
St. Croix 2	0.87 [0.24]	0.22 [0.07]	46 [25]	4.70	22	1.15
St. Croix 3	0.53 [0.08]	0.16 [0.11]	81 [7]	4.21	29	1.88
Cape North	0.85 [0.35]	0.57 [0.32]	47 [33]	2.45	95	1.18
Gypsumville	0.90 [0.42]	0.14 [0.08]	—	7.63	53	1.03
Averages	**0.80**	**0.26**	**—**	**4.64**	—	**1.28**
Chillagoe	1.95 [0.73]	0.84 [0.44]	53 [18]	2.32	—	0.46

Gypsumville data from Czok (1990); Chillagoe (limestone) data from Lundberg (1977)
(All measurements in centimetres with sample standard deviation given in brackets)

of frost debris (shillow) which prohibits rillen development. Vertical faces where debris cannot accumulate display more frequent karren, but ideal friability of the gypsum may preclude their formation there. Essentially three factors prevent rillenkarren formation on steep sites, (i) soil, till or debris cover, (ii) faster mechanical weathering and (iii) adverse lithologic properties of the rock itself. These same constraints are dominant upon limestone rillenkarren as well.

Measurements included counting the number of rillenkarren troughs along a ten centimetre line across the strike of the surface, determination of depth with a profile gauge and slope with a Suunto clinometer. All measurements were taken approximately half way down the length of the karren. Table I lists the summary statistics, where N is the number of ten centimetre samples taken. It is seen that mean width is similar at all sites of medium slope, although standard deviations are high, attesting to the variability of individual measurements. Czok's (1990) measurements from a colder, drier quarry site at Gypsumville, Manitoba, are included and are similar to the Nova Scotia sites. The width tends to reduce with increasing slope as seen generally at St. Croix site no. 3 and more specifically in Table II. This figure shows that although the relationship is subject to a great deal of variance an overall inverse trend is present.

DISCUSSION

There appear to be two distinct shapes associated with the small solution karren on young gypsum surfaces; (1) rillenkarren, typically elongate channels oriented straight down slope on the exposed surfaces; and (2) pits (enclosed

depressions with rounded bottoms and sharp rims). The pits occur on slopes of less than 10°, while the rillenkarren develop wherever sufficient slope is provided to allow gravitational flow. No one distinct boundary value could be established because rillenkarren were found on slopes of as little as 3°, while pitting extended to slopes as steep as 10°. Glew (1976) found that 8° was the lower slope limit for experiments with plaster rillenkarren and artificial rainfall. It appears that the rougher natural slopes permit rill formation at lower gradients than this.

Mean width – depth ratios were calculated. There is a great deal of noise associated with the results, but the three St. Croix sites exhibited the same average (about 4.5:1), while the Cape North site was lower (about 2.5:1) because of a much larger average depth. Mean width – depth ratio at the Manitoba site was 7.6:1. There are no obvious reasons for these differences, although differing age or lithology may be suggested.

Figure 4 compares some previously reported width measurements for limestone rillenkarren with the measures in gypsum and plaster of Paris. The gypsum karren are on average only half as wide as the limestone karren, although some of the gypsum rills approached the mean width of the limestone rillenkarren.

TABLE II

Gypsum Rillenkarren Summary Statistics

Site	Relationship between Width (W) and Slope (S)	
St. Croix 1	W = 1.09 – 0.00710S	R2 = 44.7%
St. Croix 2	W = 1.28 – 0.00884S	R2 = 86.1%
St. Croix 3	W = 1.22 – 0.00846S	R2 = 43.1%
Cape North	W = 1.03 – 0.00426S	R2 = 19.8 %

(All measurements in centimetres)

Rillenkarren grow to occupy all available space along the strike of a surface of sufficient slope, with channels of a width that is characteristic. From their experiments with inclined blocks of plaster exposed to artificial rainfall and from observations on natural limestone blocks in a landslide pile, Glew and Ford (1980) suggested that this colonising process typically occurs in two or three distinct stages. In the first one or two stages rills that are very narrow and shallow are formed and quickly coalesce laterally in pairs or triplets (no more) to create a new generation of wider rillen. These then coalesce in pairs (rarely more) to achieve the stable, tightly packed, final pattern with its characteristic width. It appears that greater solubility of gypsum favours deeper entrenchment at a given initial rill width, terminating the lateral coalescence process when mean width is only about half of that achieved on typical rilling limestones (fine grained to phanitic). Alternatively, the karren assemblages measured at the Nova Scotia and Manitoba sites were still in the earlier stages of growth, with one or more lateral coalescence steps still to occur. Given the range of their gradients, exposure ages and lithology, it seems unlikely that all could be in the intermediate stages of coalescence at the time of our sampling. Glew (1976) found that lateral coalescence on plaster was completed on the lowest gradients (8°) after 500 hours of simulated rainfall at a constant rate of 35 mm per hour. Stable mean width then was ~0.75 cm. Climatic normals for the Nova Scotia sites predict annual rainfall of 700 mm, which would permit attainment of stable mean widths within the first 25 years of their exposure at Glew's dissolution rates. This

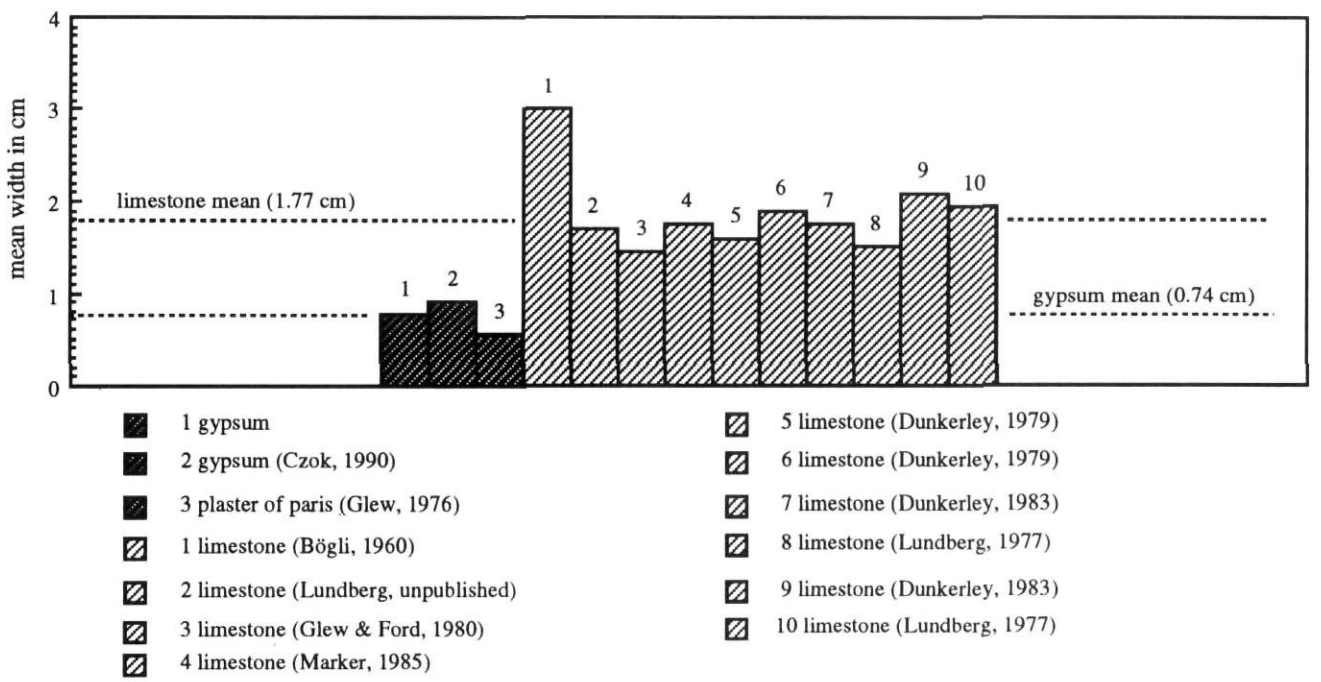

FIGURE 4. Mean widths of natural limestone, gypsum and plaster dissolutional rillen compared.

Largeurs moyennes des lapiès selon que la dissolution se fait dans du gyspse, du plâtre ou du calcaire.

age estimate accords well with the known or supposed maximum ages of these rillen. The 0.85-0.90 cm mean widths formed on all except extreme slopes in Nova Scotia and Manitoba therefore appears to be the stable natural widths of rillenkarren on a range of gypsums that are a little coarser-grained than standard plaster of Paris. They are achieved within a few decades of exposure where mean annual rainfall is between 100 and 1000 mm per year.

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APPENDIX I

DEFINITIONS FOR KARST FEATURES (KARREN) LISTED IN FIGURE 1

Rillenkarren	(linear) packed channels commencing at crest of slope; 1-3 cm wide. Extinguish downslope. Rainfall-gererated, no decantation[1].
Spitzkarren	small pinnaclelike solution sculpturing a few centimetres in height[3].
Tritkarren	(heelprints) arcuate headwall, flat floor, open in downslope direction. Normally 10-30 cm in direction[1].
Rinnenkarren	(solution runnels) linear channels showing increased width and depth downslope.
Kluftkarren	(grikes) Major joint or fault-guides solution clefts. Normally 1-10 min length. Master features in most karren assemblages, segregating clint blocks (Flachkarren) between them[1].
Rundkarren	develop beneath the cover (subsoil)... resemble solution runnels except that the ribs between get rounded by the omnipresent acidulated blacket[2].
Hohlkarren	when runnels form under slight soil cover or merely become clogged with organic debris and vegetation, the extra CO_2 engendered by the organic material and the sponge action of the soils and vegetation enhance the solution of the bedrock in the bottom of the runnel, giving it a baglike cross section wider at the bottom than at the top[3].
Deckenkarren	(pendants) are residual pillars of rock between anastomosing channels. They may be as much as 1 m long. They can be carved by water draining up, down or along the contact[1].
Pits	circular, elliptical, to highly irregular plan forms, with rounded or tapering floors, > 1.0 cm in diameter[1].
Kamenitzas	(solution pans) rounded, elliptical, to highly irregular plan forms; planar, usually horizontal floors in bedrock or fill, > 1.0 cm in diameter[1].

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2. Jennings, J.N., 1985. Karst Geomorphology. Basil Blackwell , Oxford, 293 p.
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